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Utilising zero-value waste textiles and fibres with design-driven technologies to create high quality products

## **Second Milestone Report**

**D9.3**

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# Second Milestone Report

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Cidetec	Söktas
Copenhagen Business School	Swerea IVF
Grado Zero Innovation	TEKO
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## 1. Summary

Trash-2-Cash is an EU funded project under the Horizon 2020 research programme. The project started in June 2015 and will be running until November 2018. It is applying Design-Driven Material Innovation (DDMI) as tool for the development routes within design, material research and manufacturing of new materials, services and products. The overall objective of the Trash-2-Cash project is to develop new materials and products *via* creative design from waste materials and industrial side or by-products from the textile and paper industries and to promote development within the creative sector by providing technology solutions for exploitation of waste streams and design for recycling. 18 partners from 10 countries have formed a cross-disciplinary team of designers, material researchers, and manufacturers and in combination with the specialist on behavioural research and cost and environmental assessments they constitute the full consortium. Having all of these specialists on board means that waste materials can be used to create new fibres that can be spun and woven, knitted or formed, into high performance textiles and composites, which can then be made into innovative new products. The full chain is represented within the project.

The design team drives the material innovation in close collaboration with the material R&D and manufacturer teams. The project flow has three iterative phases called “Cycles” that repeat specific steps. The end/beginning of each Cycle corresponds with a milestone, the delivery of prototypes. The Second Milestone has now been reached for the Trash-2-Cash project by finalizing the second Cycle, Cycle B, meaning that we have produced the second set of prototypes. These are smaller pieces of material of regenerated cellulose fibres and regenerated polyester fibres that have been made from waste materials. The prototypes produced during Cycle B will be evaluated by Life Cycle Assessments to facilitate communication of the potential of the future product. The perception by the potential consumer by recycled products has been evaluated through consumer behavioural research. The prototypes will be further developed during the final Cycle of the project, the refinement Cycle (Cycle C), in order to refine the material samples into product prototypes. The DDMI approach gives the design team the assignment to influence the further development of these materials into high quality products.

## 2. Introduction

### The Trash-2-Cash project

Trash-2-Cash is an EU funded project under the Horizon 2020 research programme that started in June 2015 and will be running until November 2018. The full title for the project is “Designed high-value products from zero-value waste textiles and fibres *via* design driven technologies”. The project is applying Design-Driven Material Innovation (DDMI) as tool for the development routes within design, material research and manufacturing of new materials, services and products.

The budget for the project is € 8,928,995 and the European Commission is supporting the project with € 7,933,461.

### Objectives

The overall objective of the Trash-2-Cash project is to develop new materials and products *via* creative design from waste materials and industrial side or by-products from the textile and paper industries and to promote development within the creative sector by providing technology solutions for exploitation of waste streams and design for recycling.

The general goals of the project are to:

- Integrate design, business and technology into a coherent discipline to establish new creative industries
- Develop new material and product opportunities *via* creative design from waste or process byproduct
- Reduce the utilization of virgin materials; improve material efficiency, decrease landfill volumes and decrease the energy consumption
- Use design for recycling with the vision of closing the material loop
- Create new business opportunities by adding the return loop of the discarded goods to be recycled into attractive products
- Promote development of the creative sector by providing technological solutions for exploitation of waste streams
- Demonstrate viable technical routes for value-chains in the creative industry.

### Consortium

A design-driven cross-disciplinary consortium combining science, technology, design and end-user is formed for the development of creative textile and reinforced plastics products from waste textiles, waste paper fibres and industrial by-products and scraps. Industrial and academic partners from the areas of textile and paper waste, processing, retailing and design set up this consortium. The full chain is represented: academic and industrial designers defining the demands and initiating the material development processes, researchers applying new technologies to bring about new material solutions from the waste materials (provided from textile waste suppliers and paper waste suppliers), and industrial partners, both small and medium size enterprises (SMEs) and larger enterprises, connected to various end-production sectors.

## List of partners

COUNTRY	PARTNERS	EXPERTISE
Sweden	RISE (Coordinator)	Development of new cellulosic materials, LCA
	TEKO	Swedish Textile & Clothing Industries' Association
	SCA Obbola	Personal care and forest products
	Swerea IVF	Research on fibrous, polymeric materials
Finland	VTT Technical Research Centre of Finland	Material Science
	Reima	Children's outdoor clothing
	Aalto University	Lignocellulose and cellulose fibre. Design research
Italy	Grado Zero Innovation	Advanced materials research and prototyping
	Material ConneXion Italia	Research and consulting on materials
	SO.F.TER SPA	Production of thermoplastic materials
Spain	Cidetec	Industrial innovation
	Maier	Aesthetical plastic component supplier for the automotive industry
Netherlands	VanBerlo	Design agency
UK	University of the Arts London	Arts, fashion and design
Denmark	Copenhagen Business School	Sustainable consumer behaviour
Turkey	Söktas	Designer and producer of cotton and blended fabrics
Slovenia	Tekstina	Supplier of design & engineered fabric solutions
Germany	Soex Group	Used textile marketing and recycling

## 3. Project description

The Trash-2-Cash project aims to progress us towards the sustainable textile industry of the future, one that benefits both people and the planet. Growing problems with paper fibre waste from the paper industry and textile fibre waste, originating from continuously increasing textile consumption, is challenged through design-driven innovation.

Every year we throw away over 3 million tonnes of textiles in the EU28 countries. In this unique collaboration between designers, scientists and manufacturers, the Trash-2-Cash project will tackle the growing problem of textile waste by developing state-of-the-art fibre recycling methods, to create profitable new high-performance fibres.

Designers, design researchers, scientists, raw-material suppliers and end-product manufacturers from across Europe make up this cross-disciplinary and cross-sectorial consortium. 18 partners, from 10 countries, are working on this Design-Driven Material Innovation (DDMI) project, where the whole supply chain is represented. Having all of these specialists on board means that new fibres can be spun and woven, knitted or formed, into high performance textiles and composites, which can then be made into innovative new products.



The partners are working together to develop state-of-the-art textile recycling technologies to produce new fibres that are “designed” for the kinds of products people want. The aim is that the new Trash-2-Cash fibres will not only “be made from waste” but will also be desired and used well before going into future recycling processes.

Together the collaborators are defining material properties and evaluating newly developed eco-efficient cotton fibre regeneration processes and polyester recycling techniques. Novel materials will be constructed – starting at the molecular level – in order to generate new textile fibres and other products that will be compatible with the environment for a sustainable future. Prototypes – for high quality fashion, performance textiles and automotive contexts - will be produced in a realistic test production environment. A schematic representation of the Trash-2-Cash concept can be found in Figure 1.

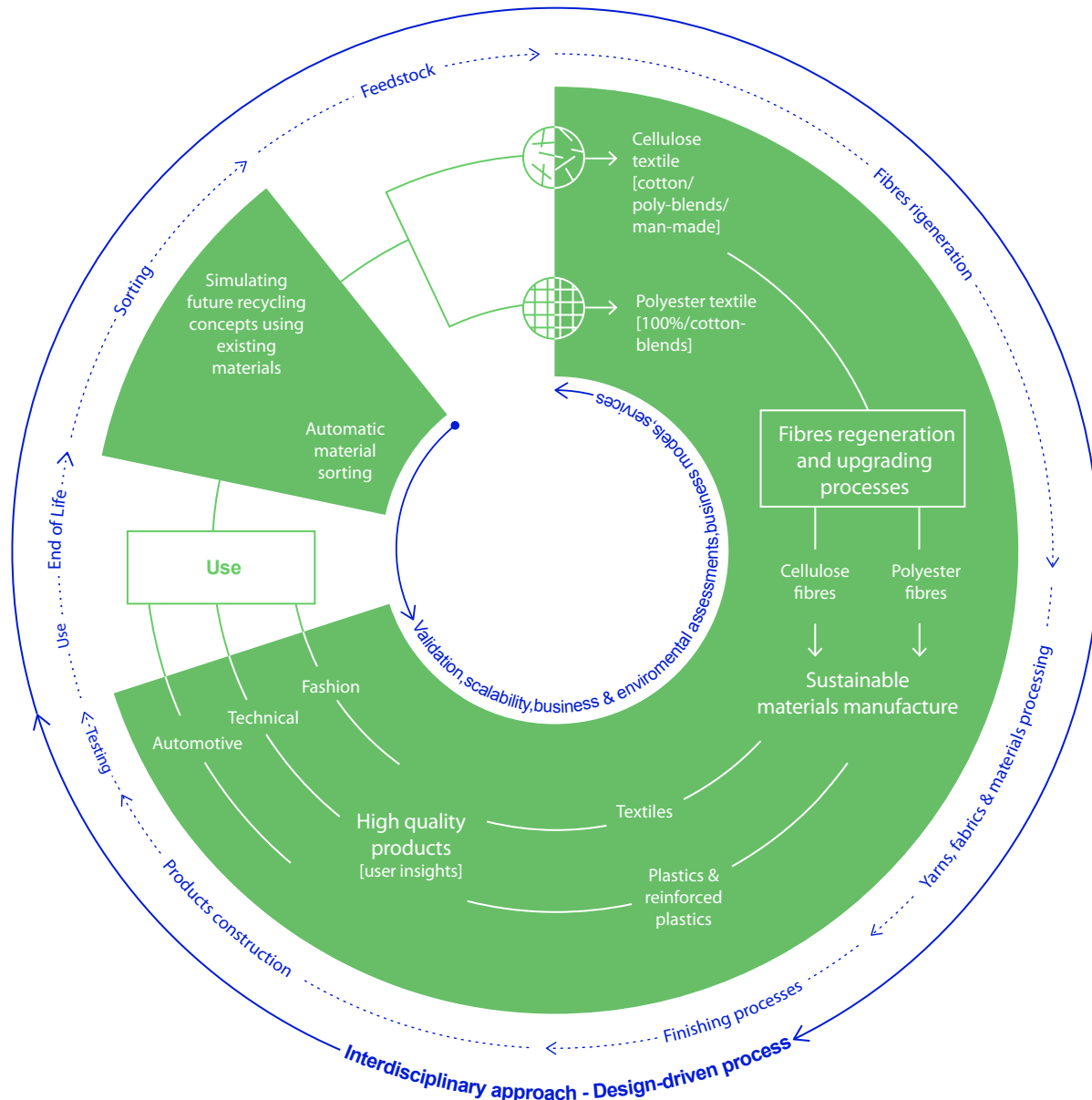


Figure 1: Schematic overview of the Trash-2-Cash circular concept

The Trash-2-Cash (T2C) team is not just aiming to create amazing new regenerated fibres, it is also pioneering Design-Driven Materials Innovation a whole new approach to developing materials.

The design team drives the material innovation in close collaboration with the material R&D team and manufacturer team. The project flow has three iterative phases called “Cycles” that repeat specific steps. The end/begging of each cycle corresponds with a milestone, the delivery of a prototype. Figure 2 shows a schematic overview of the work packages and the iterative Cycles.

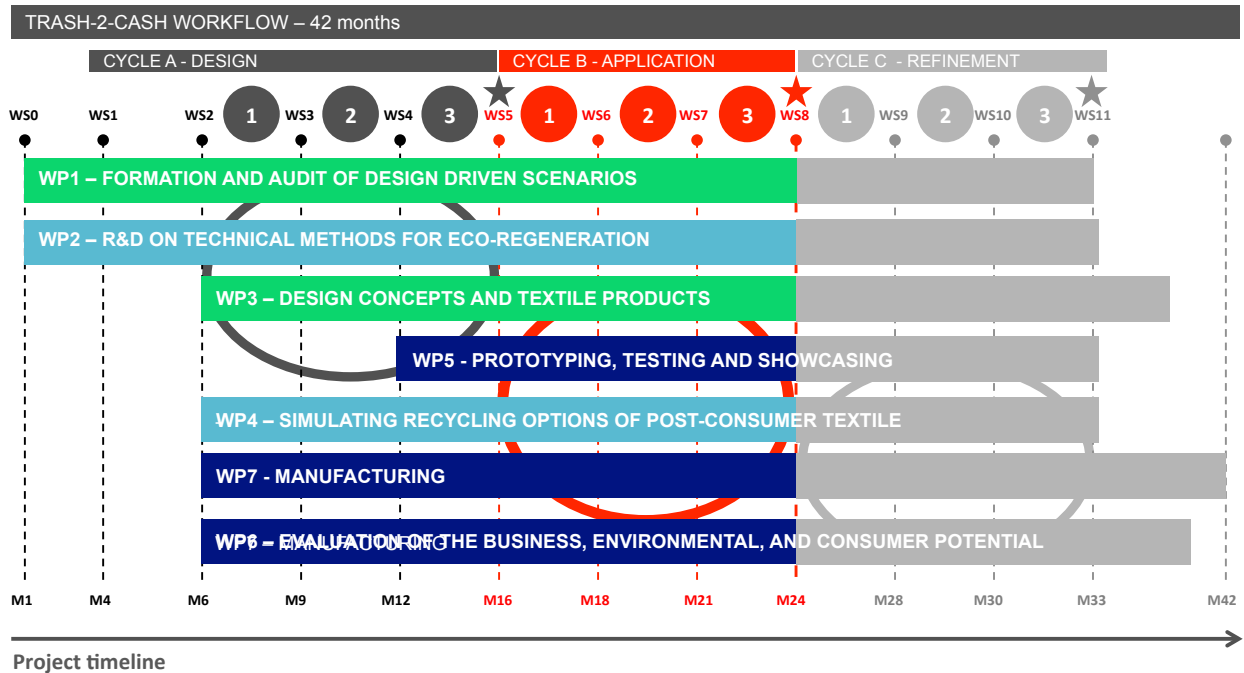


Figure 2: Schematic overview of the workflow so far (Milestone 2 – Cycle B) basing on workshops in relation with months, Cycles, steps, work packages

## 4. The second Cycle and the second Milestone

### Overall work

The overall work during Cycle B has been focussed on analysing the outcome of Cycle A and reaching to the new requirements for the development of the next prototypes. The work within the second Cycle, combining the knowledge of the three streams: designers, materials R&D, and manufacturers has resulted in the second prototype, whose completion is connected to the second Milestone of the project. The design team has refined the prototype material through exchange with the other two streams. The Manufacturing team has been in continuous communication with the designers in order to adjust the design to production conditions and vice versa. The prototypes produced during Cycle A have been evaluated by life cycle assessments in order to estimate the potential of the prototype on an environmental and business level. These exchange processes are continuously occurring in the project and are accentuated by the workshops involving the whole consortium every third month. The overall exchange process is described in Figure 3.

## PROCESS

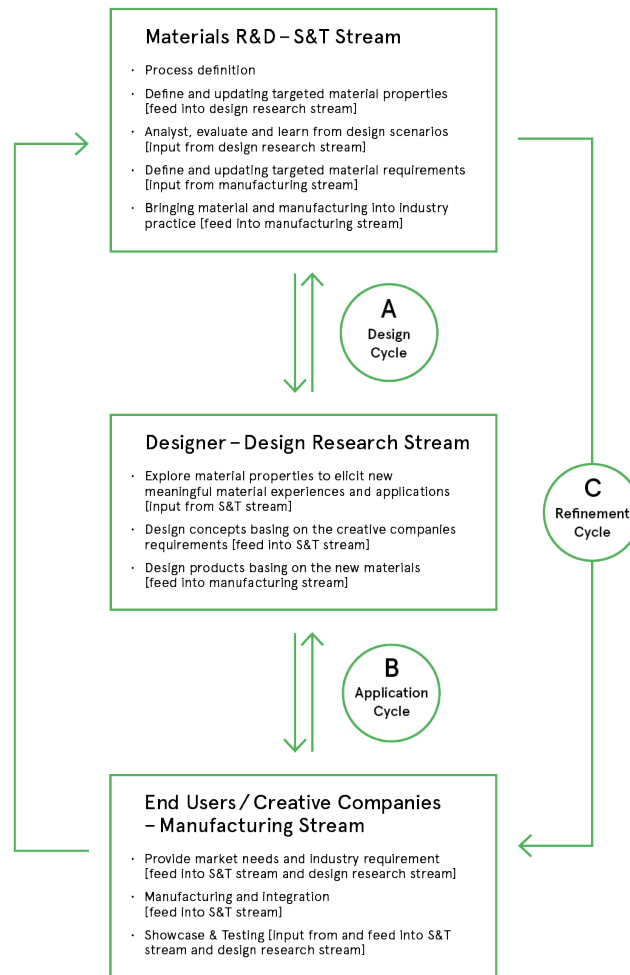


Figure 3: The Trash-2-Cash process, including the three streams: Design Research Stream, Materials R&D Stream, and Manufacturing Stream

The prototypes completed during Cycle B are samples of fabrics (woven, non-woven, knitted) and reinforced plastics. The fabrics produced are based on cellulose (CEL), polyester (PES), or a combination of the two in order to tailor specific fabric properties. The reinforced plastics consist of different fabrics in combination with plastics making them suitable for the thought applications.

During Cycle B the work related to prototype 2 has been reported in 20 confidential deliverables.

### Work within the work packages

A summary of the work performed within the work packages (WPs) 1-9 can be found below.

## WP1 Formation and audit of design driven scenarios

**WP leader: Material ConneXion Italia**

### **Aim of WP**

In the T2C project WP1 continues to have the main aim to set up and manage the material researcher-designer-manufacturer dialogue in the overall project. It means to foster the interdisciplinary approach and the design-driven methodology into the whole T2C workflow, supporting, facilitating and creating the right exchanges among the different competencies related to the implementation work packages (WP 2, 3, 4, 5, and 6). This objective is mainly executed during specific meetings (workshops) and also supporting the dialogue during the main actions between one meeting and the next one.

WP1 has the role to assure an effective, consistent and constant exchange process among the three streams (R&D, design, manufacturing) on a solid framework, in order to allow to designers, manufacturers, and material scientists to take part in the process into which usually they are not “taken into account”: scientific and technology process (R&D of new eco-fibres), prototyping and manufacturing of the new materials from the eco-fibres (yarns/fabric processing, plastic/reinforced plastic manufacturing), creative processes (design of products from new materials).

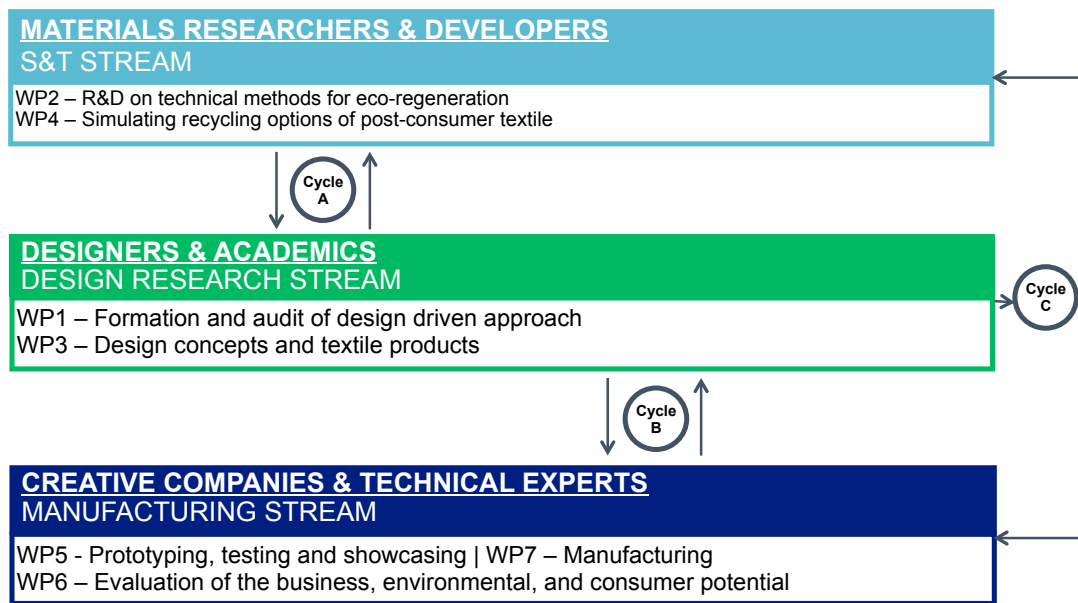


Figure 4: General T2C process: three competences/R&I streams in an interdisciplinary collaboration

The core of the T2C methodology is represented by the “circular concept” of the workflow of the project in which the three main streams have three iterative phases called “Cycles” characterized by 3 iterative steps. The end/beginning of each Cycle corresponds with a milestone and specific outcomes (1<sup>st</sup> milestone: fibres prototypes; 2<sup>nd</sup> milestone: materials prototypes; 3<sup>rd</sup> milestone: products prototypes). This project structure (Cycles, steps, workshops) is helping WP1 to audit the knowledge transfer processes, with the proper exchange of information in accordance with activities and tasks, as well as the interdisciplinary approach basing on a design-driven methodology.

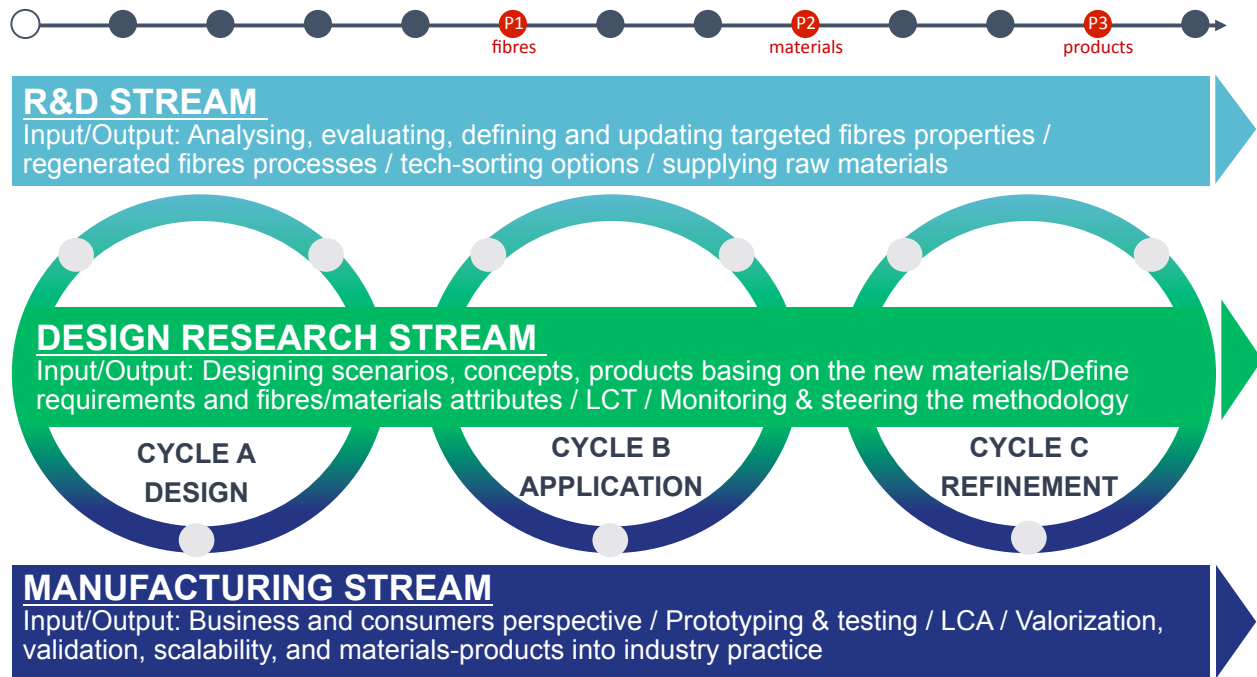


Figure 5: General T2C methodology: 3 main streams of competencies with exchanges into 3 iterative cycles, characterized by 3 iterative steps, during 12 interdisciplinary workshops

In order to create a more systematic and controlled process, the partners take three design (for re-cycling) steps in each Cycle: starting with the analysis of the potentialities, moving in the definition of new requirements, and ending with the development of solutions related to the level of each Cycle. The steps, displayed in Figure 6, are always executed in the three streams.



Figure 6: 3 iterative steps in each iterative Cycle

The iteration at Cycle and step level, permits to achieve different objectives in the project process and also to reduce the “knowledge, approach cultural gap” among the three streams/competencies.

The dialogue and the interdisciplinary approach are mainly achieved through regular workshops, a total of 12, 4 for each Cycle, in which all partners are involved and have an active role. The workshops are experimental & exploratory, and are set up as “platforms of discussion” referring to design culture and tools, having the aim to:

- implement and refine the inter-dialogue among the 3 streams
- achieve specific inputs/outputs from the 3 streams;
- develop effective knowledge transfer activities, fruitful hands-on sessions with specific outcomes;
- construct ‘wizard’ discussions to achieve common decisions and address issues.

Each workshop is planned case-by-case with specific aims, basing on the specific phase of the project and considering specific actions and outcomes.

### Tasks during Cycle B

Cycle B planned to have the execution only one task - “Set up and monitor the material researcher-designer-manufacturer exchanges” that deals with the preparation and set up of workshops (WS) and activities have to be executed in each meeting. In this way this task has constantly implemented and refined the dialogue among the three streams also in Cycle B, monitoring the process exchange itself, and supporting the progress of the Design-Driven Material Innovation methodology (DDMI).

In Cycle B the task had also the main role to harmonize and align the streams basing on the specific timeline of the R&D processes. Considering that was not possible to proceed with same timeline for the three R&D processes, it has been necessary to split them but re-aligning internally the interdisciplinary among competencies and the specific Cycle-steps.

In Cycle B, the WP1 partners have organized and set up 4 workshops, from M16 to M24, associated to the start/end of the 3 steps of the Cycle (1-analyse potentialities; 2-define requirements; 3-develop solutions), that is WS05, WS06, WS07, WS08.

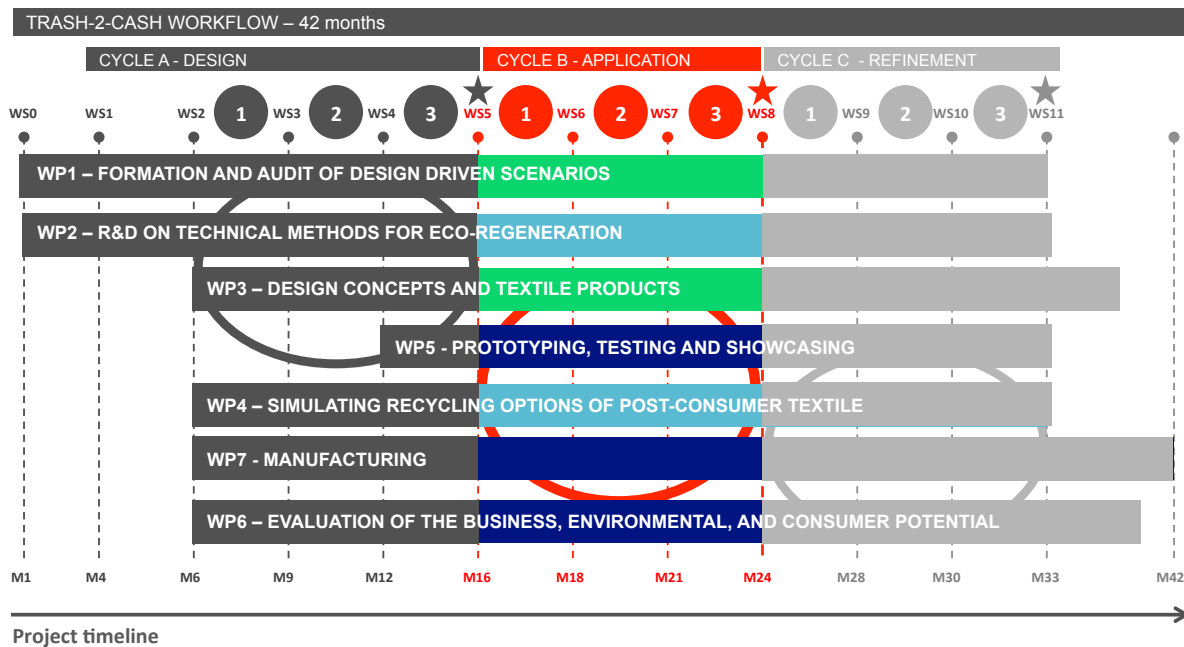


Figure 7: Schematic overview of the Cycle B workflow basing on workshops in relation with months, Cycles, steps, work packages

Below follows a short description of the 4 workshops taking into account the design-driven process:

**WS05 – Taking in charge design concept areas**

12<sup>th</sup> - 13<sup>th</sup> September 2016 in Copenhagen [Denmark] – Host partner: Copenhagen Business School

Main objectives and activities: to discuss and analyse prototypes fibres – 1<sup>st</sup> milestone [WP2], to match design briefs development with specific responsible design partners [WP3], and to set up and discuss about prototyping/testing activities [WP5] in order to provide inputs and set up valorisation plan, next design phase, treatment and finishing experimentations, and primary testing activities.

**WS06 – Starting the analysis of design concepts**

21<sup>st</sup> - 22<sup>nd</sup> November 2016 in London [England] – Host partner: Chelsea College of Arts [UAL]

Main objectives and activities: results from and discussion about primary testing/valorization plan, finishing technologies, and new prototypes [WP5]; common presentations and reflections on design concepts to generate primary inputs/outputs from Life Cycle Thinking (LCT; circular approach) to design stream [WP3]; primary input from scalability analysis [WP7].

**WS07 – Starting the evaluation of design concepts for improvements**

21<sup>st</sup> - 22<sup>nd</sup> - 23<sup>rd</sup> February 2017 in Forlì [Italy] – Host partner: Celanese - So.F.TER. SpA

Main objectives and activities: design concepts evaluation through the LCT approach and decisions for next step: finalizing P2 and WS08 final selection; presentation and discussion about primary outcomes of prototypes 2 [material prototypes -textiles and composites - from WP5], about PES-R&D streams, and updating and common discussion about other R&D streams [WP2]; inputs from sorting analysis outcomes [WP4], and for the study about perceived barriers of end-users [consumers] and primary LCA [WP6]; new issues/options from scalability analysis [WP7].

**WS08 – Finalizing the evaluation of design concepts for selection**

16<sup>th</sup> - 17<sup>th</sup> May 2017 in Bilbao [Spain] – Host partner: Cidetec-IK4 and Maier

Main objectives and activities: presentation and discussion about prototypes 2-materials [2nd Milestone] with finishing/treatments from manufacturing perspective [WP5]; Design concepts selection (4 kind of categories) for the next design phase [WP3] and further analysis [WP7-WP6-WP5]; Interdisciplinary approach to support design in a circular evaluation: LCT+LCA [WP3-WP6]; primary reasoning on storytelling, marketing and business perspective of design concepts/products [WP6-WP8].

***Results***

The main results of WP1 are the workshops themselves and their outcomes, inputs/outputs, tools, activities, homework, as well as the structure of the hands-on sessions. As written earlier each workshop has its own set up in order to achieve specific objectives, with an exploratory and experimental approach. Deep descriptions of the workshops activities, agendas, structures, input/output will be summarized in two dedicate reports [public and confidential version] at the end of Cycle C. At this stage of the project no public results are available.

***Further work/Tasks in progress***

Set up and monitor the material researcher-designer-manufacturer exchanges will run until the achievement of 3<sup>rd</sup> milestone, that is 3<sup>rd</sup> generation of eco-fibres, from which will be obtained the 3<sup>rd</sup> generation of materials, from which will be obtained the final product prototypes for showcasing. The WP will go ahead to organize and define the last 3 workshops of Cycle C – WS09, WS10, WS11 - and to audit the overall project process basing on the design-driven methodology.

## **WP2 R&D on technical methods for eco-regeneration (from recycled materials to fibres)**

***WP leader: VTT Technical Research Centre of Finland***

### ***Aim of WP***

The aim of the WP is to provide required raw materials samples for demonstrator preparation and develop required technologies for refining and spinning.

### ***Tasks during Cycle B***

During this Cycle it has been possible to overcome certain challenges in material availability and reach the schedule.

### ***Results***

The facility to produce re-dissolved and regenerated loncell-F (r-CEL) fibres of postconsumer cotton has been subjected to installation works due to relocation to a new laboratory space. When now applying the new setup, pre-treated cotton for prototype 3 has progressed with 4 samples prepared for preliminary spinning test by Aalto.

Washed polyester residual and recovered low molar mass polyester for depolymerisation from both loncell-F and the carbamate process has been provided to test by Swerea IVF. Monomer Bis(2-Hydroxyethyl) terephthalate from depolymerization was produced with a nano-catalyst, analysed and re-polymerized achieving a polymer with typical polyester properties, except that the colour was greenish. Further purification is under preparation and larger volume of virgin-mixed monomer will be available for the prototypes.

Applying shredded PES samples for extrusion has now been improved by an agglomeration step and achieved marked improvement, some 5-10 times in feeding rates. The current dosing rates have now reached 60% of the maximum rates. Softer has also studied the moisture sensitivity of the samples and is preparing a drying process for the next runs. Two chain extenders for the reactive extrusion study have been defined.

### ***Further work/Tasks in progress***

The main future work for the next Cycle is to produce larger quantities of regenerated fibers (r-CEL, r-PES) for demonstration materials requested, to prepare PES samples and to perform chain extension extrusion tests.



## WP3 Design concepts and textile products

**WP leader:** Aalto University, School of Arts, Design and Architecture

### Aim of WP

The aim of WP3 is to create innovative materials to be realized in garment (textile) and automotive (composites) product applications via multidisciplinary collaboration. In addition, new business model and process innovations can be created around these concepts.

The product design process has a centric (design driven) role of the project. WP3 feeds to R&D/S&T Stream (WP2 (fiber forming, 4 automatic textile waste sorting) but also to the Manufacturer stream (WP 5, product prototyping and WP 7, Scalability/commercializing studies) by providing the material & product requirements. In addition, the innovation can be found from new process and business model. The business potential and LCA of the products is studied in WP6.

In Cycle B (Application Cycle) the specifying of textile prototypes to be made has been in focus. The designer stream fed the textile material manufacturing specifications of P2, constructed from design concepts to Manufacturer partners (WP5) and fed to S&T stream the material attribute requests of P3 fiber properties (WP2).

Figure 8 illustrates the design process in WP3, and how the project Cycles - from A to C - are in relation to the tasks in package. Every brief has a different role depending on process stage. In Cycle B, the Concept Design -task has been a strong role in creation of data for the briefs (2<sup>nd</sup> and 3<sup>rd</sup>). Thus, the briefs gather the data being created in other tasks and also design related data being generated in WP2 and WP5 by specifying the material attributes of prototypes to be done from developed concepts. The next phase of the process is to evaluate and select the concepts and product types to the product design stage.

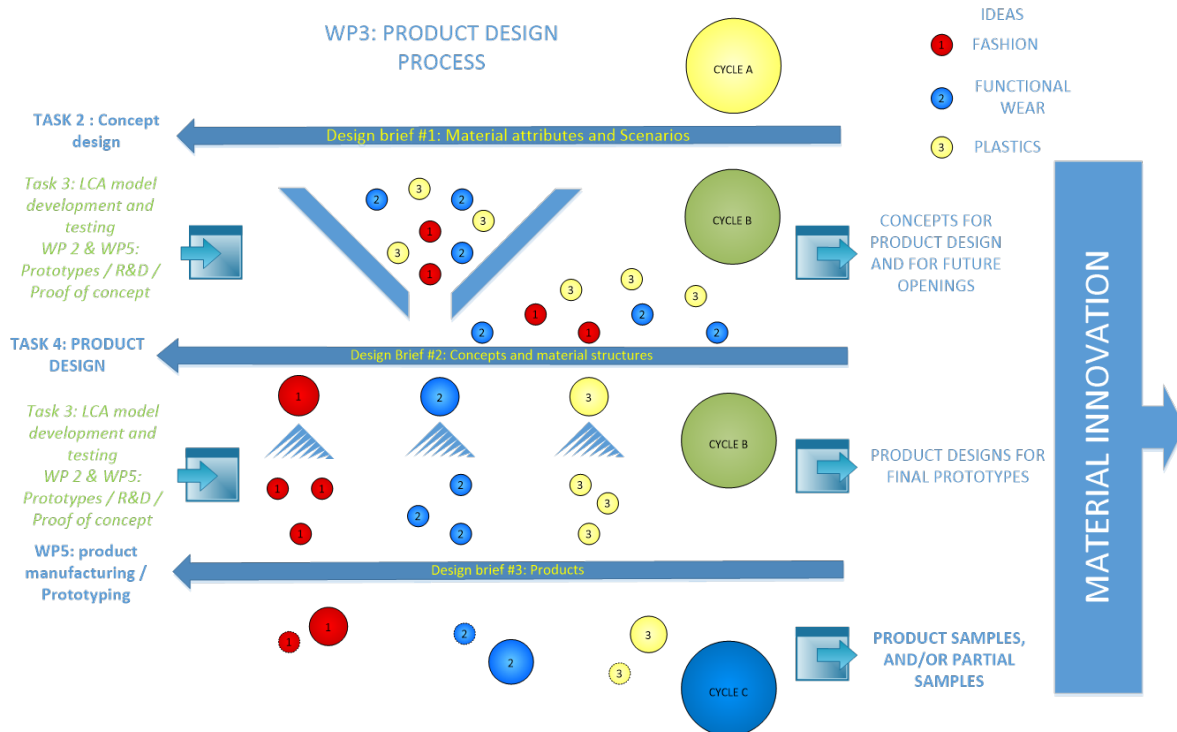


Figure 8: The product design process in WP3

### Tasks during Cycle B

A framework for the design process was developed and implemented during Cycle B. Stage 1 – Concept Design tasks were undertaken during and between WS05 Copenhagen (M16) to WS06 London (M18). Design concept areas were

developed and material liaison officers for each area - cellulose, polyester, and composite appointed to communicate material attributes desired by the designers to the R&D materials stream in WP5. Stage 2 – Interdisciplinary Specification tasks were undertaken during and between WS06 to WS07 Forlì (M21). ‘Design Specification Sheet’ templates were developed and sheets completed for each design concept to link design requirements with Science and technology information for clear communication across the consortium. Stage 3 – Concept Refinement tasks were undertaken during and between WS07 to WS08 Bilbao (M24). Design concepts were evaluated and grouped into material clusters and design and manufacturing teams working on each concept to develop concepts in preparation for WS08 identified.

The life cycle analysis-task runs in parallel to the concept design -task ensuring the design concepts are informed by life cycle thinking. To date three Life Cycle Tools have been developed; Iteration 1: introducing life cycle thinking into the concept design process cycle, WS06 London (M18). Iteration 2: Interdisciplinary life cycle development WS07 Forlì (M21). Iteration 3 - Circular Evaluation - materials, WS08 Bilbao (M24).

The methodology insights about successes and weaknesses in knowledge exchange and the design methodology are being used to inform the workshop design and delivery in WP1 and steer the project from cycle B into C. A methodology paper has been published and the final structure of the report for the deliverable in M39 has been updated, the deadline for this report has been moved to accommodate other delays within the project to ensure that all activities within the project are captured and reflected upon within the DDMI methodology developed.

### ***Results***

The second brief was delivered in the middle of the Cycle B in January 2017. It presented the clustered concept ideas and material properties of them. The clustering was made by identifying similarities from material property perspective. The brief provided input to the prototyping (WP3) of P2 textile materials (knitted and woven) and reinforced textile materials, in addition it provided the fiber attributes for P3. As the target is to design for recycling all the materials used in concepts and end-products to be designed are recyclable with Ioncell-F or the polyester regeneration -process and utilizing automatic sorting of textile waste. There are also process improvement ideas, where some steps can be skipped over in order to decrease the production steps in fiber forming, which could also lead to explicitly new business model. The enhancing of textile material properties has been essential in each product concept.

### ***Further work/Tasks in progress***

The design concepts will be frozen and selected concepts (master cases) will proceed to product design stage. The product development work will continue as an iterative process, and specifying of P3 will be constructed with help of results from P2 -sample round. Iteration 4 of the life cycle tool will be developed based on consortium feedback from WS08 and further more focused feedback from designers and expert groups. Iteration 4 will be focused on circular evaluation for Product design, reflecting Concept Design -task completion and product design beginning within the WP.

Each tool iteration (1 to 4) is being evaluated and refined with collaboration from experts in the consortium with the aim to develop generic life cycle thinking tools for potential use beyond the T2C project, at both material and product levels

## **WP4 Simulation recycling options of post-consumer textiles**

***WP leader: RISE***

### ***Aim of WP***

The first purpose of WP4 is to simulate recycling options based on its quality properties. Aging of cellulose and polyester fibres in textile during long-time services decreases the quality of the fibres. The intention is to understand consequences for circularity of the fibres regenerated within the Trash-Cash project, specifically the cellulose fibres. The question to be answered is if the produced Trash-2-Cash fibres will have the quality enough to be regenerated again. The second purpose of WP4 deals with the need of improvement in sorting technology to obtain high quality post-consumer textiles required for the Trash-2-Cash regeneration processes.

### ***Tasks during Cycle B***

Task 1 and 2 are connected to the first purpose and are evaluating the effect of laundering and use on molecular quality aspects of cellulosic textile fibres. In task 1 have cellulosic textiles fibres and blends with polyester been laundered (and some also used) and chemically analyzed by its molecular molar mass properties. Task 2 discusses the obtained data from task 1 with focus on the consequences for the circularity of the fibres. The attempt is to optimize the feedstock flows to the Trash-2-Cash processes.

In Task 3 with focus on the second purpose is assessing the state-of-the art and potential of fully automated near-infrared technology for sorting of post-consumer non-wearable textiles. Clothing can be rather complex material with many layers and attributes. In this evaluation only monolayer garment has been considered. The feedstock and sorting aspects based on the test results have been fed into Cycle B for the evaluation of the Trash-2-Cash concepts/prototypes. The results from this test study will also be presented in a public report.

## **WP5 Prototyping testing and showcasing**

***WP leader: Cidetec***

### ***Aim of WP***

The objective of WP5 is to develop two iterations of the prototyping activities: firstly the application Cycle (Cycle B), with the aim to generate the material samples of Prototype 2, and the first step for the screening/testing of the preliminary finishing treatments; secondly the refinement Cycle (Cycle C), with the aim to generate the 3<sup>rd</sup> stage of development, producing ready-to-product materials with final finishing treatments to be used for the validation of the manufacturing value chains. Both iterations are in closed-loop with other WPs, especially with WP2, 3 and 7:

- WP2 provides P1 regenerated fibres and yarns based on cellulose and polyester (r-CEL and r-PES) to WP5
- WP3 provides designer's specifications to WP5, that at the same time generate the inputs for the subsequent iteration Cycle.
- WP7 receives inputs of processes at lab-pilot scale used in WP5

The project ends with the realization of selected showcases of products and their evaluation through the analysis of the feedback coming from the consumers, as well as from the judgment of the designers. The material samples developed in this work package will also be used for dissemination purposes, for example by exhibiting or by creating photographs or video.

### ***Tasks during Cycle B***

The main Tasks the WP5 have been working on:

- *Task 1. Valorization of materials for P2.*
- *Task 2. Finishing technologies step 1.*
- *Task 3. Creation of material samples for Prototype 2.*

Task 1 has focused on the testing of the P1 material samples for improving the manufacturing of the P2 and P3, respectively for r-CEL-derived prototypes and r-PES-derived prototypes.

In Task 2, first tuning/testing activities for the identification of the preliminary finishing treatments to be applied on the Prototype 2 have been made, starting from the input of the Task 1 and the design specifications coming from WP3.

In Task 3, different P2 material samples based on r-CEL and r-PES have been manufactured: fibres/yarns, knitted, woven and non-woven fabrics and reinforced plastics. Also preliminary finishing treatments coming from the first iteration have been applied on them.

### ***Results***

Based on the designer's specifications coming from WP3, different P2 samples have been produced: r-PES fiber has been produced through a depolymerization and repolymerization process, followed by melt spun into yarn. Also r-CEL yarn has been produced through Ioncell-F process. With these regenerated yarns, different woven, non-woven and knitted fabrics have been produced, some of them being mono material (based on 100% r-CEL or 100% r-PES) and some of them being hybrids (a mixture of r-CEL and r-PES).

Moreover, different reinforced plastics have been produced with the regenerated fabrics, using in all the cases recyclable thermoset resins than can be chemically dissolved at the end of life, being possible in this way the recovery of the fabric and the resin for later reuses.

Finally, different preliminary treatments have been applied on the fabrics (printing, eco-repellency and laser) and reinforced plastics (laser) to obtain different finishing depending on the requirements defined in WP3.

### ***Further work/Tasks in progress***

During next period, Task 3 will be completed by production of r-PES pellets derived from chain extension and melt mixing of residual PES, with which yarns and plastics will later be manufactured.

To complete Cycle B, all the P2 samples manufactured will be tested according to the requirements established by designers in order to validate them and provide guidelines for the third stage production (Cycle C).



## **WP6 Evaluation of the business, environmental, and consumer potential of developed design concepts**

***WP leader: Copenhagen Business School***

### ***Aim of WP***

In WP6, the involved partners worked on three main aspects: 1) Life Cycle Inventory (LCI) analysis of Prototype 2, 2) Life Cycle Assessment (LCA) of Prototype 2 and 3) Identification of barriers towards recycled textile products perceived by consumers.

### ***Tasks during Cycle B***

#### **Life Cycle Cost**

The main goal of this task, running from M10 to M42, is to ensure the industrial relevance and impact of the research efforts, analyzing scalability of the processes used at lab and pilot scale for mass production. Testing, validation and quality assurance are also envisaged as means to ensure the industrial relevance and impact of the T2C production model. Another objective of the task it is that to analyze the industrial and market potential of the new supply chain concepts and business models that will stem from the T2C project outcomes. Finally, the economic evaluation of the more promising design concepts through the LCC analysis, that will be conducted in 3 iterations, for supporting the design-driven development of the design concepts into product concepts, and allowing the identification of economic hotspots in the life cycle of the design concepts. Already the first iteration related to mass and energy balances of the production processes from the feedstock sorted and pre-treated, till the production of the fibres was made and delivered, as well as the first iteration of the LCC analysis, made on the Prototype 1 (fibres), delivered in two confidential reports.

#### **Life Cycle Assessment**

The objective is to ensure the final prototypes are competitive in terms of their environmental performance. The work is carried out by means of interactive sessions at the project workshops and environmental evaluation in four iterations, using LCA. The second LCA iteration was finalized in December 2016. This included screening assessments of processes and chemicals of relevance for the project. This provided preliminary insights regarding which process parameters that are most important in environmental terms, and process models which can be adjusted to new data, new combinations of stages in the pre-treatments, and new combinations of pre-treatments and recovering technologies, and thus constitute the basis for further modelling. In the spring of 2017, the focus was to contribute to workshop sessions in order to steer the development of the design concepts into an environmentally sound direction, to enable selection of three sufficiently defined and environmentally promising design concepts for the deeper analyses of Cycle C (including the third LCA iteration). In WS07, this was done through the Life Cycle Thinking (LCT) session organised by UAL. Before the workshop, all design concepts were screened in an internal RISE workshop with regard to two criteria: whether they have the potential to evolve into environmentally competitive end products (e.g., taking into account the results of LCA iterations 0 and 1), and whether they are sufficiently defined for being studied in the third LCA iteration. In WS08, a circular analyses session – combining the LCT and LCA perspectives – was organised jointly by UAL and RISE. To prepare, a homework package were given to the designers, to help them evaluate and develop the design concepts from an LCT and LCA perspective. In the session, each life cycle stage were further discussed and developed by interaction with the experts on materials, sorting, market, etc. This session concretized and clarified the design concepts, and the corresponding end products, which enabled input to session C of WS08, in which the prospective end products were scored with regard to (among others) environmental criteria, to be used as a basis for the selection for the products to be studied in Cycle C.

#### **Consumer perspective**

The main objective is to explore consumers' acceptance towards recycled textile products and once an understanding is generated, to increase the acceptance of recycled products. Consumer's acceptance of new products depends strongly on their perceptions of barriers towards recycled textile consumption. This is fundamental knowledge to then, in a second step, to develop targeted strategies to enhance recycled textile acceptance and finally, consumption. To identify consumers' barriers towards recycled textile consumption, a representative consumer survey in four countries (Germany, Poland, Sweden and the U.S.) was developed and carried out. Several barriers towards recycled textiles

could be identified – among those are price, quality or hygiene. Regarding price, consumers across all countries were willing to pay only 60% of the price of an equivalent product made of conventional material. This holds true for general fashion as well as the product categories jeans and t-shirts. To differentiate between objectively existing barriers and perceived barriers, experts within and outside the project were interviewed. Results indicate that while hygiene and quality are merely perceived barriers from consumers' point of view, price is indeed higher – at least in the beginning. To explore consumers' willingness to pay, an online experiment using design concepts developed in the project is currently designed and will be carried out in 2017/2018. To address the “only” perceived barriers, communication strategies will be developed and tested on their effectiveness.

## **WP7 Manufacturing**

***WP leader: Grado Zero Innovation***

### ***Aim of WP***

Main aim of the work package is to describe, conceptualize and rate the production processes, facilitating the scaling-up of materials and technologies used to make the prototypes from lab and pilot-scale (as used in the work package 2 - fibres and pellets of 1<sup>st</sup> generation - and subsequently in work package 5 - materials prototypes and product demos for showcasing), to industrial scale. All manufacturing steps are in this work package fully described and analyzed, providing all the validation tools and guidelines to successfully shift the productions processes to real industrial environments. The work package also supports the industrial validation of new supply chain concepts and business models (faced in the work package 6), gathering - from the manufacturing perspective - all the relevant information and data needed for creating and growing market and commercial opportunities based on recycled fibres and derived products for the green and circular economy.

### ***Tasks during Cycle B***

Conceptualising scalability of the future benign processes

In this task, the concepts worked out within earlier work packages, from design concepts to materials prototypes, were assessed and conceptualized/modelled in order to give the prerequisites for investigating scale-up parameters as required for the final products (*Technical Garments, Novel Garments, Plastic and Reinforced Plastic Parts*).

Scale-up analysis for manufacturing the new products on industrial volume

According with the specifications established by the designers (in work package 3), and the information gathered from the testing of the prototypes developed (in work package 5), methods for scaling-up the new concepts were outlined and carried out. This task will lead to the final scaling-up parameters for mass production due at M40. Manufacturing data were communicated to work package 6.

### ***Results***

No public results are available.

### ***Further work/Tasks in progress***

While the scalability conceptualization is finished with the end of the Cycle B (M24), the scaling-up analysis on the manufacturing of the new products on industrial volume will continue till M42. This task will lead to the final scaling-up parameters for mass production due at M40. A new is started in M25, as the Cycle C started, that related to the validation of strengths and weaknesses of the new product concepts for industrial scale production. In this task the quality of the prototypes for the final showcasing, manufactured in the work package 5, will be assessed and verified on the base of market-available benchmarks, and finally validated. Qualification of systems and equipment will be part of this validation, as well as the supervision of all the manufacturing processes.



## **WP8 Dissemination, exploitation and networking**

***WP leader: The University of the Arts London***

### ***Aim of WP***

The aim of this work package is to deliver a coherent project identity which builds both external awareness of the project as well as a sense of unity within the consortium. The aim is also to create impact in the dissemination by engaging stakeholders and general interest groups as well as using established academic and industry routes. The work package also aims to build a robust exploitation path for the Key Exploitable Results. The connection between WP8 and the other work packages is via the Dissemination Board meetings, updates and workshop sessions at consortium meetings. The WP8 team also works directly with partners on leveraging stories for the blog and through podcast interviews, via emails, skypes and 1:1 meetings.

### ***Tasks during Cycle B***

The main tasks during this Cycle have been through the Development of Dissemination Tools and Products for which a revised version of the T2C concept diagram was created and the T2C project website, brochure and slides were all updated and reissued. A new Restricted Area was created using Project Place (<https://www.projectplace.com/>); and the blog and social media coverage increased in audience, with subscribers totalling 935 (Blog 118; Twitter 412; Facebook 146; Instagram 259). The podcast series has now published 5 interviews, and reached a total of 691 listeners. The partners have hosted 4 events and workshops, including: Dynamic Duos in London (UAL); Material Village, Milan Furniture Fair in Milan (MCI); Global Change Awards (AA/ACChem) in Stockholm; and Solutions Lab at Copenhagen Fashion Summit (AA/ACChem). The total audience for these events is estimated at 4230.

### ***Results***

The highlight of this period is the publication of scientific papers, journals and conferences with 4 papers being presented at 3 conferences in 3 countries reaching approximately 15,000 people. T2C partners Aalto Arts and UAL presented 2 papers at the Circular Transitions Conference (23-24 November 2016, London) where T2C partners Helena Wedin (RISE), SOEX and Rosie Hornbuckle (UAL) also co-created an exhibit for the conference exhibition. These papers provided insights into how design knowledge can be applied within collaborative projects, and the challenges and benefits of a Design Driven Material Innovation approach as a tool in the development of materials in the circular economy. Aalto Chem presented their research into upscaling textile waste through a novel recycling process they have developed for cotton / polyester blended waste textiles, which has the potential to reduce the amount 'fast fashion' garments that current end up in landfill sites, at a meeting of the American Chemical Society (ACS) (2 April 2017, San Francisco). Marjaana Tanttu from Aalto University also presented - at the The 12<sup>th</sup> European Academy of Design Conference (EAD12, 12-14 April 2017, Rome - a paper with Kirsi Niinimäki which shared experiences about collaboration in a design-driven material innovation project.

### ***Further work/Tasks in progress***

The new website will be launched in September 2017, in time for WS09 in Helsinki. For Outreaching and Public Engagement the WP08 team are creating a press release for use by all partners; templates and new image folders for partners own dissemination work. The Dissemination Board meetings continue now each month, focusing on devising a reverse-engineered time line working back from the final meeting in November 2018, jointly deciding on how to allocate the funding for events.

Forthcoming publications: Postcards from Across Europe: Exploring the Edges of Regenerated Fibre Development and Design Driven Material Innovation (conference paper and presentation by Earley & Hornbuckle, 30 May 2017, Autex 2017 in Corfu, Greece); Co-Designing a Circular Economy: An Interdisciplinary Lifecycle Tool (conference paper and presentation by Goldsworthy & Ellams, 7 June 2017, 6<sup>th</sup> Fibre Recycling Conference, Leeds, UK). Recyclable Thermoset Composites Derived from Waste Textiles, Biennial National Congress Matcomp 2017, San Sebastian (conference poster by Nerea Markaide, Virginie M. Boucher, Aratz Genua, Sarah Montes, Hans J. Grande, Alaitz Rekondo, 21-23 June 2017, San Sebastian, Spain); A Meditation on the Faces of Circular Fashion Research (conference paper and presentation by Earley & Hornbuckle, Intersections Conference, Loughborough University, London, 13 September 2017).



## **WP9 Management and coordination**

***WP leader: RISE***

### ***Aim of WP***

The work package is handling the management and coordination of the Trash-2-Cash project.

### ***Tasks during Cycle B***

Tasks during Cycle B have included setting up the workshops in collaboration with WP1 and the planning and reporting of deliverables to the European Commission. Handling of the financial and IP management have also been major tasks during this part of the project.

## **5. Further work**

The second Milestone is not only the end of Cycle B, but also the start of Cycle C, the refinement Cycle. During Cycle C, the developed design concepts will be frozen and selected design concepts will proceed to the product prototype stage, directing the further work that will result in achieving Prototype 3 and Milestone 3. Guidelines for production of P3 will be based on the evaluation of the manufactured P2 taking into account all the aspects that are available to be evaluated by all the various competences in the consortium.